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A Mass Mortality of Northern Bay Scallops, *Argopecten irradians irradians*, Following a Severe Spring Rainstorm[1]

by

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Abstract. Observations of a mass mortality of northern bay scallops, *Argopecten irradians irradians,* were made shortly after a severe rainstorm on 5–6 June 1982 during which more than 21 cm of rain fell on the Poquonock River area in Groton, Connecticut, USA. Mortality levels approached 100% at locations highest in the estuary, and decreased with distance from the head, and with depth. Observed levels of bay scallop mortality resulting from estimated periods of exposure to reduced salinities compared well with published laboratory determinations. All other lines of evidence also support the conclusion that the bay scallop mass mortality resulted directly from low salinities incurred by the storm.

INTRODUCTION

THE EFFECTS OF salinity reductions on estuarine fauna depend on the nature of the morphological, physiological, and behavioral attributes that particular species possess for coping with changes in salinity (see KINNE, 1964, for general review). Most bivalve mollusks are especially susceptible to salinity fluctuations because of their limited mobility and virtual inability to osmoregulate over wide ranges of salinity (GILLES, 1975).

As epibenthic estuarine inhabitants, bay scallops may suffer considerable exposure to freshets in the natural environment (BROOM, 1976). GUTSELL (1930) reported mortalities of *Argopecten irradians concentricus* in North Carolina that were apparently related to reduced salinities and suggested that freshets may be extremely destructive to natural bay scallop populations.

In this paper, we report a mass mortality of northern bay scallops, *Argopecten irradians irradians* (Lamarck, 1819), that occurred in the Poquonock River in Groton, Connecticut following a severe rainstorm on 5–6 June 1982, during which more than 21 cm of rain was recorded (City of Groton Water Filtration Plant, unpublished data).

AREA OF STUDY

The Poquonock River is a shallow, well-flushed estuary adjoining the eastern portion of Long Island Sound (Figure 1). The mean depth of the river is 0.95 m, the average tidal range is 0.79 m, and the residual volume of the estuary at mean low water (MLW) is 945,000 m^3 (2.5×10^8 gals; Tettelbach, unpublished data). Although detailed salinity profiles are unavailable, Rafferty (unpublished data) reports that, during the summer, salinity levels generally range from 20 to 30‰ at the head and 26 to 35‰ toward the mouth of the river.

The major source of freshwater input to the Poquonock River is Great Brook. The flow of this stream is regulated by the City of Groton Water Filtration Plant (COGWFP), which is located about 0.5 km north of the estuary's head. Discharge over the weirs of the plant is considered to be approximately equivalent to the total volume of fresh-

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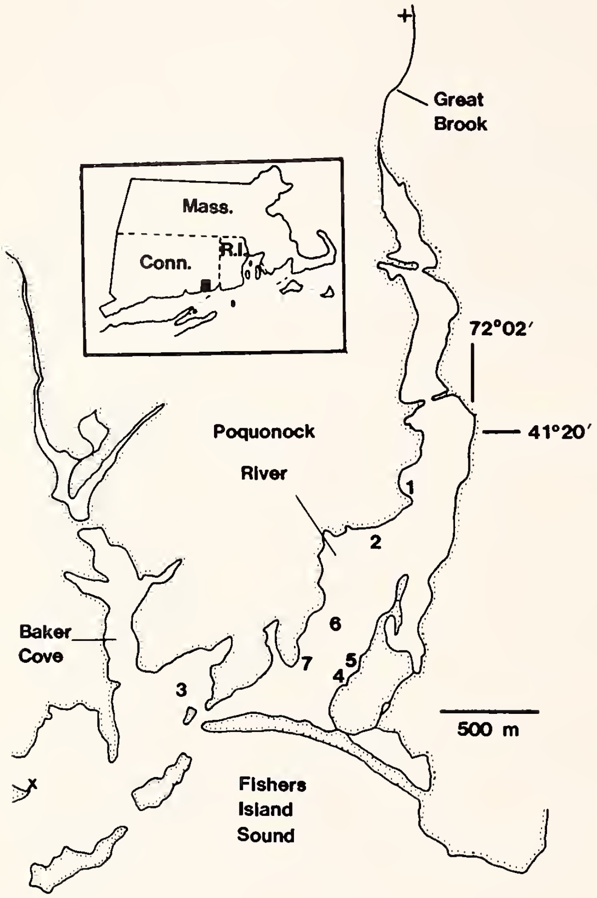

Figure 1

Map of the Poquonock River area, Groton, Connecticut, USA, with insert illustrating its location in New England. Numbers refer to sampling stations; ×, location of the USGS tidal gauge; +, location of the City of Groton Water Filtration Plant.

water that enters the Poquonock River (Stevens, personal communication).

An indigenous population of northern bay scallops exists in the lower half of the estuary. Supplemental plantings of hatchery-reared scallops have been undertaken in recent years to augment the recreational fishery (Stewart *et al.*, 1981).

Materials and Methods

Initial observations of the effects of the June 1982 rainstorm involved a qualitative survey of the scallop stocks and other estuarine fauna by biologist divers along the west side of the estuary (stations 1, 2) on 8 June 1982 (Figure 1). Water samples were collected and salinities determined by specific gravity. Tidal stage at the time of sampling was calculated in relation to values recorded at a tidal gauge (USGS, 1982, 1983) located about 1 km from the mouth of the Poquonock River (Figure 1).

On 10 June 1982, the numbers of live bay scallops and dead scallops with both valves still connected were counted *in situ* in 0.25-m^2 quadrats haphazardly placed in areas of known scallop concentrations (stations 3, 4). Ambient temperature and salinity measurements were taken with a Yellow Springs Instrument Co. Salinity-Conductivity-Temperature meter. On 11 June 1982, additional 0.25-m^2 quadrat counts were made at two depth strata (<1 m, >1 m) at station 5. Only dead scallops with all or part of the tissues remaining were counted in addition to live scallops.

Two mortality estimates were computed based on quadrat counts of live and dead bay scallops with intact hinges:

maximum mortality (%)

$$= \left(1 - \frac{\text{no. of live scallops}}{\begin{array}{c}\text{no. of live scallops}\\ + \text{ no. of dead scallops}\\ \text{(with or without tissue)}\end{array}}\right) \times 100;$$

minimum mortality (%)

$$= \left(1 - \frac{\text{no. of live scallops}}{\begin{array}{c}\text{no. of live scallops}\\ + \text{ no. of dead scallops}\\ \text{(with tissue)}\end{array}}\right) \times 100$$

Further observations of bay scallop mortality were made at station 6 on 17 June 1982 when pearl nets (34 × 34 × 28 cm high pyramidal nets constructed of plastic-coated wire and plastic mesh) containing hatchery-reared juveniles were examined. The nets were put in place on 27 May 1982: stocking density was 50 scallops/net (=550/m^2); mean length of the scallops was 4.7 mm. Mesh size of the nets was 2–3 mm, a size that effectively excluded all predators.

In order to compare conditions in the estuary and the status of bay scallop stocks following a less severe storm than that which occurred on 5–6 June 1982, observations were made at station 7 one and four days after a storm on 10 April 1983 during which 7.8 cm of rain was recorded (COGWFP, unpublished data). Temperature and salinity measurements were made in addition to qualitative surveys of the bay scallop population.

Results

Bay scallop mortality estimates and measurements of environmental parameters made at each station in the Poquonock River on the given dates are summarized in Table 1.

Initial observations made on 8 June 1982 along the western side of the Poquonock River (stations 1, 2, Figure 2) revealed that 100% of the bay scallops encountered (40–50 individuals) were dead. All were gaping widely; tissues were flaccid and runny, and showed no or only slight evidence of mechanical damage from scavengers (see Fig-

Table 1

Summary of bay scallop mortality estimates and parameter measurements acquired at the Poquonock River sampling stations following the 5–6 June 1982 rainstorm.

Station no.*	Water depth (m)	Bottom salinity (‰)	Bottom temperature (°C)	Estimated bay scallop mortality (%)	Time of sampling (h) (+) after high tide (−) before high tide	Sampling date (1982)
1	1	2.6	—	100	+2.5	June 8
2	1	3.7	—	100	+4.0	June 8
6	1	—	—	100	—	June 17
5	0.50–1.0	—	—	90.5 (min.)	—	June 11
	1.0–1.5	—	—	67.7 (min.)	—	June 11
4	0.75–1.5	14.8	16.5	91.3 (max.) 86.2 (min.)	−1.75	June 10
3	1	13.5	16.5	48.0 (max.) 0–5 (min.)	−2.25	June 10

* Stations are listed in order of increasing distance from the head of the estuary.

ures 2A, B). Other dead and dying animals in this area included juvenile winter flounder (*Pseudopleuronectes americanus*), cockles (*Laevicardium mortoni*), and sea cucumbers (*Sclerodactyla* [=*Thyone*] *briareus*), the latter being greatly bloated. Green crabs, *Carcinus maenas*, were common and active; no moribund individuals were observed.

Counts from the 12 0.25-m² quadrats made on 10 June 1982 at station 3 yielded 29 live and 27 dead scallops. All of the dead individuals seen completely lacked tissue, except for three scallops that were observed outside the quadrats. Based on these counts, the estimate of maximum bay scallop mortality at station 3 was computed to be 48%, while the minimum estimate was 0–5%.

The 12 quadrat samples taken at station 4 on 10 June 1982 yielded the following totals: 8 live and 50 dead scallops. Virtually all of the dead individuals still had part or all of the viscera present inside the shell. The minimum estimate of mortality at this location was 86.2%, while maximum mortality was calculated to be 91.3%.

Quadrat counts made at station 5 on 11 June 1982 were as follows: 0.75–1 m depth—15 live, 124 dead scallops in 20 0.25-m² quadrats; 1–1.5 m depth—31 live, 65 dead scallops in 20 0.25-m² quadrats. Estimates of minimum mortality for these two depth strata were calculated to be 90.5% and 67.7% respectively. The composite mortality estimate for station 5 was 80.4%, which was close to the estimated minimum mortality for nearby station 4 (86.2%) where depth strata were not differentiated.

The hatchery-reared juvenile bay scallops that were being held in pearl nets at station 6 were all found dead on 17 June 1982.

Observations made on 11 and 14 April 1983 in an area of bay scallop concentration (station 7) revealed that all scallops exhibited normal behavior, with velar tentacles extended, and immediately closed their valves when disturbed. Temperature and salinity measurements taken just above the sediment surface on 11 and 14 April were 9.0°C, 25.7‰, and 11.0°C, 11‰ respectively. There was no evidence of mortality resulting from reduced salinity.

DISCUSSION

On the basis of the observations described above, it seems extremely likely that the mass mortality of northern bay scallops that occurred in the Poquonock River immediately following the severe rainstorm of 5–6 June 1982 resulted from reduced salinity, as opposed to any other factor such as predation, disease, siltation, or exposure to toxic materials. The presence of large numbers of dead bay scallops with intact tissues, higher survivorship of scallops in deeper strata, and decreasing scallop mortality levels at points farther from the head of the estuary all support the above conclusion. Supplemental evidence also comes from the fact that the survival rate of scallops planted in pearl nets at station 6 two weeks after the 5–6 June rainstorm was 95% for the period July–October (Rhodes and Widman, unpublished data).

Based on the salinities recorded in the vicinity of stations 1 and 2 on 8 June 1982 (see Table 1), it appears that this area of the river may have been subjected to salinities of 4‰ or lower for as much as 48 h (and probably longer) after the storm ended. It is assumed that salinities had dropped to near these levels by the time the storm was over.

If the above assumptions are valid, then the observed mortalities of bay scallops due to exposure to these reduced salinities are consistent with laboratory results obtained by MERCALDO & RHODES (1982). These authors found that after 6 h exposure to salinities of 0 and 5‰ at temperatures of 13 and 19°C, juvenile northern bay scallops suffered no mortality; but all were dead after 24 h. When exposed to a salinity of 10‰ at these temperatures, scallops suffered 100% mortality after 48 h.

SANDERS *et al.* (1965) stated that the magnitude and

A

B

C

duration of salinity fluctuations are influenced by the size, volume, and depth of an estuary, by tidal amplitude, and by the amount (and rate) of freshwater runoff. Although such factors are important in affecting the extent to which organisms are stressed by periods of salinity reduction due to rainstorms and/or riverine discharge, it is also evident that the timing of a storm event is extremely important. As is apparent from the results obtained by MERCALDO & RHODES (1982), survival of bay scallops at low salinities is greater at lower temperatures. Therefore, storm events leading to reduced salinities may be more harmful in warmer months of the year when metabolic demands of estuarine organisms are likely to be greater.

Observations following the rainstorm of 10 April 1983 revealed that although a large amount of precipitation was recorded (7.8 cm), the volume of freshwater entering the Poquonock River, 15 million gallons/day (mgd), represented but 6% of the residual volume of the Poquonock River at MLW. Resultant salinity reductions were apparently not severe enough to directly cause any bay scallop mortality. In contrast to this, an average of 250 mgd overflowed the weirs of the COGWFP during the period 6–8 June 1982, representing a daily input equal to the residual volume of the Poquonock River at MLW. This inundation of the Poquonock River resulted in the drastic reduction in salinities and the subsequent mass mortality of bay scallops.

Under the most extreme conditions, reduced salinities resulting from storm events may contribute to the local extinction of certain populations of estuarine invertebrates. ANDREWS (1973) reported that many estuarine species of sponges, tunicates, echinoderms, and mollusks were eliminated from portions of Chesapeake Bay following tropical storm Agnes in June 1972. Although rainstorms as severe as that of 5–6 June 1982 in the Poquonock River and that of June 1972 in Chesapeake Bay may occur only once every several hundred years at a specific locality, such events may be seen as important recurring processes that can cause mass mortalities of certain invertebrate species.

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Figure 2

Dead northern bay scallops, *Argopecten irradians irradians,* photographed four days after the 5–6 June 1982 rainstorm in the Poquonock River. Note the flaccid tissue remains, some of which are being fed on by scavengers: the grass shrimp *Palaemonetes* sp. (A) and the mud snail *Ilyanassa obsoleta* (B). Scavengers initially fed mostly on scallop viscera, leaving the adductor muscle intact (C).